CLAIMS

We claim:

1. A variable speed wind turbine system comprising:

a wound rotor induction generator;

a torque controller coupled to the generator to control generator torque using field oriented control; and

a pitch controller coupled to the generator to perform pitch regulation based on generator rotor speed and operating independently of the torque controller.

2. The system defined in Claim 1 wherein the pitch controller comprises a proportional, integral derivative (PID) pitch controller.

3. The system defined in Claim 1 wherein the pitch controller comprises a proportional, integral (PI) pitch controller.

4. The system defined in Claim 1 wherein the pitch controller comprises a proportional, derivative (PD) pitch controller.

5. The system defined in Claim 1 wherein the pitch controller comprises a Lag-Lead controller.

6. The system defined in Claim 1 wherein the pitch controller comprises a Lead-Lag controller.

7. The system defined in Claim 1 where the pitch controller comprises an open loop controller with a derivative term.

8. The system defined in Claim 1 wherein the wound rotor induction generator comprises a non-slip ring induction generator.

9. The system defined in Claim 1 wherein the torque controller comprises a dampening filter to reduce commanded torque based on detected oscillation motion between turbine blades and the generator.

10. A variable speed system comprising:

a wound rotor induction generation means for generating power;

a torque controlling means for controlling generator torque using field oriented control; and

a pitch controlling means for performing pitch regulation based on generator rotor speed and operating independently of the torque controller.

11. The system defined in Claim 10 wherein the pitch controlling means comprises a proportional, integral derivative (PID) pitch controller.

12. A variable speed wind turbine system comprising:

a wound rotor induction generator;

a torque controller coupled to the generator to control generator torque using field oriented control; and

a proportional, integral derivative (PID) pitch controller coupled to the generator to perform pitch regulation based on generator rotor speed.

13. The system defined in Claim 12 wherein the wound rotor induction generator comprises a non-slip ring induction generator.

14. The system defined in Claim 12 wherein the power controller controls the generator power and torque as a function of generator speed.

15. The system defined in Claim 12 wherein the power controller controls the generator power from a power look up table (LUT) as a function of generator speed using field oriented control (FOC).

16. The system defined in Claim 12 wherein the power controller comprises a look up table (LUT) of power and corresponding generator rotor speeds, and wherein the power controller interpolates the LUT using a measured generator rotor speed to determine a target output power, from which the torque controller determines a desired generator torque using the measured generator rotor speed.

17. The system defined in Claim 16 wherein the power controller causes the generator to follow a predetermined power-speed curve encoded in the LUT.

18. The system defined in Claim 12 wherein the power controller comprises:

a LUT encoding a predetermined power-speed curve, wherein the LUT outputs a target output power in response to a measured generator rotor speed;

a comparator to generate a power error indication based on a comparison of actual output power to the target output power;

a proportional, integral (PI) controller coupled to the power error indication to generate an adjusted actual output power in response to the calculated power error indication; and

a divider to generate a commanded torque in response to the measured generator rotor speed and the adjusted actual output power.

19. The system defined in Claim 18 further comprising a feedforward dampening term filter coupled to change the commanded torque in response to the measured generator rotor speed.

20. The system defined in Claim 12 wherein the power controller controls generator torque by commanding a required rotor current vector which interacts with an identified flux vector to produce a desired generator torque.

21. The system defined in Claim 12 wherein the power controller controls torque at least from cut-in to rated wind speeds.

22. The system defined in Claim 12 wherein the power controller controls torque from cut-in to rated wind speeds.

23. The system defined in Claim 12 wherein the power controller causes the generator to follow a predetermined power-speed curve.

24. The system defined in Claim 12 wherein the power controller commands a preselected constant torque to slow the wound rotor.

25. The system defined in Claim 24 wherein the preselected constant torque comprises a maximum preselected constant torque.

26. The system defined in Claim 12 further comprising a generator speed indication coupled to inputs of the power controller and the PID controller.

27. The system defined in Claim 12 wherein the power controller operates independently of the PID pitch controller.

28. The system defined in Claim 12 wherein the PID pitch controller comprises a closed loop PID controller with pitch angle being fed back.

29. The system defined in Claim 12 wherein the PID pitch controller comprises an open loop controller with a derivative term.

30. The system defined in Claim 12 wherein the PID pitch controller generates a pitch velocity to perform pitch regulation.

31. The system defined in Claim 12 further comprises a wind turbine having at least one blade coupled to the generator, and wherein the PID pitch controller controls generator rotor speed by pitching said at least one blade.

32. The system defined in Claim 31 wherein the PID pitch controller pitches said at least one blade based on a

difference in actual generator rotor speed and commanded generator rotor speed.

33. The system defined in Claim 12 further comprising:

a comparator to generate speed error indication based on a comparison between a measured generator rotor speed and a target generator rotor speed, and wherein the PID pitch controller generates an output pitch velocity value in response to the speed error indication; and

a non-linear LUT coupled to output a command voltage to drive a proportional valve to effect pitching action in response to the pitch velocity value.

34. A variable speed wind turbine having a plurality of blades comprising:

a doubly-fed generator having a wound rotor;

a power converter coupled to the wound rotor of the doubly-fed generator and having a LUT containing an encoded power-speed curve, wherein the power converter samples generator rotor speed, updates a desired output power from the LUT using the generator rotor speed, determines a new torque based on an updated desired output power, and calculates a new current vector that is impressed upon the wound rotor; and

a closed loop proportional, integral derivative (PID) pitch controller coupled to pitch the plurality of blades based on generator rotor speed.

35. The turbine defined in Claim 34 wherein the power converter and PID pitch controller operate independently.

36. The turbine defined in Claim 34 wherein the power converter holds power constant above rated wind speeds.

37. The turbine defined in Claim 36 wherein the power converter holds power constant by controlling rotor current to provide the proper torque.

38. The turbine defined in Claim 34 wherein the PID pitch controller generates a pitch velocity to perform pitch regulation.

39. The turbine defined in Claim 34 wherein the PID pitch controller pitches the plurality of blades based on a difference in actual generator rotor speed and commanded generator rotor speed.

40. The turbine defined in Claim 34 further comprising:

a comparator to generate a speed error indication based on a comparison between a measure generator rotor speed and a target generator rotor speed, and wherein the PID pitch controller generates a pitch velocity command in response to the speed error indication; and

a non-linear LUT coupled to output a drive voltage to be applied to a proportional value to accomplish blade pitch motion in response to the pitch velocity command.

41. A variable speed wind turbine having a plurality of blades comprising:

a doubly-fed generation means for generating power, wherein the generation means has a wound rotor;

a power converting means for transforming alternating current to direct current, wherein the power converting means has a LUT containing an encoded power-speed curve, wherein the power converting means includes means for sampling generator rotor speed, means for updating a desired output power from the LUT using the generator rotor speed, means for determining a new torque based on an updated desired output power, and means for calculating a new current vector that is impressed upon the wound rotor; and

a closed loop proportional, integral derivative (PID) pitch controlling means for pitching the plurality of blades based on generator rotor speed.

42. The turbine defined in Claim 41 wherein the power converting means and PID pitch controlling means operate independently.

43. The turbine defined in Claim 41 wherein the power converting means includes means for holding power constant above rated wind speeds.

44. The turbine defined in Claim 43 wherein the power converting means includes means for holding power constant by controlling rotor current to provide the proper torque.

45. A method of controlling generator power comprising the steps of:

measuring generator rotor speed;

accessing a LUT using measured rotor speed to obtain a target output power;

comparing actual output power and the target output power;

generating a commanded torque by adjusting a torque calculation to maintain a predetermined output based on comparison of actual output power to the target output power.

46. The method defined in Claim 45 wherein the commanded torque comprises a predetermined constant torque to slow down the generator rotor speed.

47. The method defined in Claim 45 wherein the predetermined constant torque comprises a maximum constant torque.

48. An apparatus for controlling generator power comprising the steps of:

means for measuring generator rotor speed;

means for accessing a LUT using measured rotor speed to obtain a target output power;

means for comparing actual output power and the target output power;

means for generating a commanded torque by adjusting a torque calculation to maintain a predetermined output based on comparison of actual output power to the target output power.

49. A method of controlling generator torque of a variable speed system, said method comprising the steps of:

identifying a stator flux vector;

commanding a rotor current vector; and

producing a desired generator torque by interacting the stator flux vector and the rotor current vector.

50. A synchronization process for a variable speed system having a generator, said process comprising the steps of:

connecting a generator stator;

connecting a generator rotor;

ramping up a rotor current; and

regulating generator torque.

51. The process defined in Claim 50 wherein the step of connecting the generator stator occurs at a first generator speed.

52. The process defined in Claim 51 wherein the step of connecting the generator rotor occurs at a sec nd generator speed

higher than the first generator speed and when rotor voltage is at a first voltage.

53. The process defined in Claim 52 wherein the step; of regulating generator torque comprises the steps of enabling a rotor side converter and gating rotor side IGBTs.

54. The process defined in Claim 52 wherein the step of regulating generator torque comprising the step of creating a current vector that is able to produce the desired torque.

55. A variable speed wind turbine system having turbine blades, the system comprising:

a wound rotor induction generator;

a torque controller coupled to the generator to control generator torque, wherein the torque controller comprises a dampening filter to reduce commanded torque based on detected oscillation motion between the turbine blades and the generator; and

a pitch controller coupled to the generator to perform pitch regulation based on generator rotor speed and operating independently of the torque controller.

56. The system defined in Claim 55 wherein the dampening filter comprises a bandpass filter with a passband centered at the resonant frequency of the generator and turbine blades and a shaft coupling the generator and turbine blades together.